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BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

FOREST INSECT INVESTIGATIONS

PROGRESS REPORT: MELANOPHILA CALIFORNICA STUDIES - 1937 SEASON

USDA Forest Service

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by
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Berkeley, California
April 20, 1938

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Forest Insect Laboratory
Berkeley, California
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PROGRESS REPORT: MELANOPHILA CALIFORNICA STUDIES - 1937 SEASON

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RESUME OF PROGRESS

The California flatheaded borer has been the object of two season's study. The results of the second year's investigations have added somewhat to our knowledge of the species. The more important findings of the past season are briefly summarized below:

The life cycle for the greater part of an emerging brood has been two or more years, with the possibility of a one year cycle yet to be determined.

Flathead brood may overwinter as incipients, fast growing larvae and prepupae. In seasonal development, incipient larvae which enter the fast growing stage usually pass into the prepupal stage before the next winter. Broods which overwinter as fast growing larvae are apparently less successful. All emerging brood passes one winter in the prepupal diapause.

Salient features of adult life have been studied, showing that feeding is a necessary adjunct to sexual maturity. Oviposition habits were followed and eggs of the species, concerning which little was previously known, were found under bark scales and were reared out. In the course of rearing, an egg parasite was discovered.

Larval studies have shown that as many as four distinct ages of incipient larvae may be present in the same section of an infested bole, with the proportion of larvae of any one age to the total brood varying inversely with the age of the group.

In a study of environmental factors, particular attention was paid to effect of host materials and to temperature. The physiological condition of the host determines the time when larvae leave the incipient stage to complete their development. The overwintering condition of the host material is important in determining emergence, and the possible importance of slash is recognized.

Development of eggs and pupae at a constant temperature were followed. Development of the emerging brood has been correlated with effective air temperatures during the spring months.

Special studies included rearings from a number of types of host materials, successful initiation of forced attacks, and continued introduction of beetles to caged trees where some evidence of attack was uncovered. In connection with the latter study it has been shown that feeding injury was correlated with the general vigor of the tree.

PROGRESS REPORT: MELANOPHILA CALIFORNICA STUDIES - 1937 SEASON.

by A. S. West, Jr.

INTRODUCTION

The study of insect losses in the California eastside ponderosa pine stands during the past few years has had as one of its objectives the realization of a better understanding of the insect species involved and their individual roles in the loss cycle. The examination of stem analysis records and plot loss records showed the prevalence of flatheaded beetles under certain conditions and indicated the possibility that these insects were of more importance than had hitherto been accepted. On the basis of this indication a definite project was set up for the study of Melanophila species.

The chief objective of these studies is to find out what role flatheads play in forest insect depredations. In achieving this objective it is necessary to have a knowledge of the biology or life history of the species involved and what the relations are between insect and host.

The place of flathead studies in the northern California program has been summed up in the Annual Progress Report of the Berkeley Laboratory as follows: "The biology of the California Flatheaded Borer is studied to furnish a background for the Tree Susceptibility project. Tree Susceptibility is studied to furnish a background for its application in cultural control by selective logging. The remaining project, an inventory of hazard, is being pushed to completion as one which will supply both a background and a plan for practical application of the results of other projects."

These flathead studies have been conducted at and near Hackamore, on the Modoc plateau in northeastern California. This area, located in typical eastside ponderosa pine stands, was selected because it contacted country where losses had been heavy and where the present timber stand over a range of site conditions reflected current insect activity in varying degree.

During 1937 a new field laboratory was constructed to facilitate the biological program. Equipment improved or developed consisted of: rearing can shelter for adult emergence studies; insectary for log rearing studies; a battery of cages for forced attack and adult life studies; tree cages over small poles for forced attack and host relation studies; instrument shelter for weather recording equipment; cellar for bark storage; and a kerosene-heated constant temperature oven for temperature studies.

Cooperation was secured with the Civilian Conservation Corps, the Regional Office of the Forest Service, the Headquarters of the Modoc National Forest, and the Asheville Laboratory, Forest Insect Investigations, for the conduction of these studies as an integral part of the service and research program for the commercial pine forests of northern California.

REVIEW OF WORK PRECEDING 1937

During the seasons of 1934 and 1935 a limited study was made of general flathead biology. The results of this work and a summary of notes, both published and unpublished, are given in a report by Salman and Bongberg (1937). Outstanding in this summary was the indication that Melanophila californica Van Dyke rather than Melanophila gentilis Lec. was the more active and important species. During the 1936 season full time was devoted to Melanophila studies, with the result that the importance of the role played by flatheaded borers was definitely established. Life history studies furnished basic information on all stages except the egg and indicated a life cycle of longer than one year. It was developed that the importance of flatheads is effected by the activity of broods of small larvae (these larvae and their galleries being collectively referred to as incipients) whose development is dependent on the condition of the host which in turn may possibly be influenced by the abnormal tissue created in the healing over of the galleries. (West, 1937b) Through technical studies it was demonstrated that the tissue healing over the gallery on the wood surface is composed of irregular parenchyma cells, largely occluded by resinous deposits. (West, 1937c) Observation at random and study on selected plots indicated that incipient flathead infestations in living trees were widespread in the eastside ponderosa pine type forests.

Continued investigations to establish the role of flatheads have hinged on the activity and development of incipient broods.

RESULTS OF STUDIES DURING THE 1937 SEASON

Life Cycle.

Length of life cycle: All indications point to a variable length of life cycle for the California Flatheaded Borer, and it would appear that for the majority of emerging brood in any one season the life cycle must have been two or more years with the condition of the host determining this developmental period. Since successive attacks generally occur in a green tree, and incipient larvae may live for several years, a mixed age brood is the rule. When conditions become suitable for brood development to the adult stage the incipient larvae of all ages enter the fast growing phase. Thus, the emerging individuals are a mixed age group. In Figure 1. the establishment of a typical mixed age incipient brood and its development to the adult stage is diagrammatically expressed.

To date there is no evidence to show that M. californica can complete its life cycle in a single year. A year is required for development from the egg of the incipient to the adult stage. Apparently host trees where such development has started in the spring are not attractive to beetles which may be in flight that season. The possibility of a one year life cycle can be determined when the results of forced attacks of the 1937 season are known.

Overwintering Stages and Seasonal Development: A majority of the total flatheaded population in a stand at any one time overwinters in the incipient stage. In a few instances overwintering broods of fast growing larvae have been observed, while the brood which is to emerge the following season overwinters in the prepupal larval stage.

Because of the existence of several overwintering stages, seasonal development presents a somewhat complex picture. As indicated in Figure 1, incipient larvae which have overwintered may continue activity as incipients throughout the season and enter the following winter, and the incipient stage may include as many as three overwintering periods. The alternative to continued activity as incipients is initiation of the fast-growing stage, which, apparently contingent on some physiological condition of the host, may begin early in the spring and is exceedingly rapid. The majority of broods entering this stage will reach the prepupal condition during the late summer and fall, while occasionally fast growing broods do not reach the prepupal stage before winter.

All emerging broods have overwintered in the prepupal stage in the winter preceding emergence. The rate of spring development is varied, for pupae may be found in April while prepupae of the emerging brood may still be found in mid-July. A pupal period of roughly one month results in emergence beginning in May and continuing until mid-August. Adults mate and begin egg deposition following a short feeding period, hence the new incipient broods are established chiefly during June and July.

Notes on Habits and Development During 1937.

Pupation: Pupae were observed in standing trees during the second week of May and earliest pupation was probably about the first of May. Since the first emergence was during the first few days of June, a pupal period of approximately one month was indicated. Considerable variation in the date of incipiency of pupation and length of the pupal period was noted in brood bark under a variety of conditions in the field.

Emergence: The first emergence in the field was noted on June 5, while emergence from rearing cans began on May 23. The presence of adults about trap trees was noted to be greatest during the first part of July while only occasional beetles were observed during the latter half of that month. Rearing can emergence was extended to mid-September by storing bark in the cellar during the spring and early summer. A progressive mortality ranging from 25 to 50 percent resulted from this "cold storage".

Populations: From 584 square feet of bark which were placed in rearing before the middle of May, 1730 adults of M. californica were collected, an average of 2.96 beetles per square foot. Although this bark was collected from a variety of sources the original populations were all established in standing trees. Random samples have shown an average incipient population of 11 individuals per square foot. It is probable that the reduction in population from incipients, just prior to the fast growing stage, to adults is in excess of 75 percent.

Observations on Adults: Adult activity was greatest during the hottest part of the day, with beetles making short sporadic flights from branch to branch or rapidly crawling. On cool days or when there was a wind, activity was distinctly limited. It has been definitely shown that feeding is a necessary adjunct of adult life. When foliage is not available, adult life is extremely short and inactive (see Table VI). Cage observations indicated that heavy feeding on needles may occur at night as well as during the day. Feeding produces an irregular injury (Figure 2) and the injured needles quickly brown and die.

Dissection of females showed that before oviposition could occur a feeding period was necessary, during which maturation of the ovaries resulted. Copulation was observed in cages where the adults had fed on foliage, following which oviposition occurred. Eggs were placed between bark scales bordering on a bark crevice. When the ovipositor, which was extended fully two-thirds the length of the abdomen, was not hidden from view, the eggs could be seen passing along the oviduct. For adults collected in the field a maximum length of life of 41 days and an average of 19.5 days was noted while adults collected from emergence cans lived approximately one week.

Egg Stage: Positive identification of eggs of M. californica by observation of oviposition was made during the 1937 season. These whitish, opaque and soft-bodied eggs are roughly flattened pear shaped in outline, although the shape is frequently distorted during the course of oviposition. The dimensions of the eggs are approximately 1 mm. in length and 2/3 mm. in width. Photographs of eggs on bark of ponderosa pine are shown in Figures 3 a and b. Counts showed eggs placed in groups of from one to 11, averaging 4.

Incipient Larvae: During the 1937 season sample counts were made to determine the age of incipient larvae found in green trees. (This determination was based on the number of growth rings peripheral to the point of origin of the gallery). At least four, and possibly five, broods of different age may be present in the same cambium area of a single green tree. The relative proportions are shown in Table I, indicating that the proportion of larvae of any one age group to the total number of larvae varies inversely with the age of the brood. Counts were also made to determine the current (1936-37 winter and spring) mortality. The results, given in Table II, show that mortality does not predominate in any one age group.

Growing larvae: Log rearing studies showed that when a tree was felled the incipient brood entered the fast growing stage almost immediately and completed development to the prepupal stage before the end of the season. It is believed that felling a green infested tree creates the same physiological condition in the host as occurs naturally when incipients enter the fast growing stage in standing trees. Although this change commonly occurs in the spring in standing trees, it can be created at any time during the summer months by felling the host tree.

Prepupal larvae: Prepupae of the brood to emerge in 1938 were first observed in the field in early August, in 1937, and were sampled in log rearings at about the same time. Normally, prepupae are found in the bark, but in thin bark trees they may enter the outer layers of the wood, as shown in Figure 4. Continued observations until the first part of December indicated no change in the prepupal brood, supporting the conclusion that the prepupal stage is in the nature of an enforced diapause requisite to further development.

Rate of growth: During the winter of 1937-38 a brief study was made of series of larvae from incipients to prepupae. Measurement gave no indication of distinct instars, and it is concluded that while growth definitely occurs even in those larvae which remain in the incipient stage several years, this growth is contingent on the condition of the host.

Host Relations.

Physiology of the host: The role of flatheads is determined by the activity and success of incipient larval broods. It is evident that continued attacks are found more often in the weaker host specimens, although initial attacks apparently may occur on any green tree. There is some justification for considering the theory that incipient galleries may weaken the host. The amount of mechanical damage is small, but in highly susceptible trees the number of galleries is large and their distribution radially, tangentially and vertically must present some obstruction to the normal conduction of nutrient solutions in the outer rings of the wood. Initial observations in connection with tree injection studies indicate that conduction may actually be interfered with as a result of the presence of these galleries. It is not unreasonable to assume that such obstruction may be detrimental to the vigor of the host, bearing in mind that the relative importance of this effect may be conditioned by factors other than the entomological one.

The physiological change in the tree which makes a suitable environment for development of brood beyond the incipient stage does not necessarily occur at the same time all over the tree. Figures 5 a and b show two aspects of a single log where the larvae are nearly full grown on one side although just entering the fast growing stage on the other.

Relation of type of host material to emergence: Although all incipient broods originate in standing green trees, development may be

completed in standing trees, slash or windfalls. In such material the amount of emergence is conditioned by the effect of external factors on the broods. In Table III the emergence per square foot of bark is indicated for a variety of material. The heavy emergence from slash raises the question as to the importance of slash as a source of brood.

Environmental Factors.

Temperature and Development: A considerable amount of data has been accumulated on the relation of temperature to brood development. The analysis of this data can best be expressed by a tabulation of statements as follows:

1. The occurrence of air temperatures down to -34° F. and bark minima of at least -9° F. during January, 1937, resulted in an almost complete mortality of larvae overwintering in the fast growing stage.

2. Laboratory tests show that mortality of prepupal larvae begins at -4.6 F. and may be as high as 50 percent at -15° F. Field samples during the spring of 1937 showed that some winter mortality of prepupae had occurred. Practically 100 percent mortality was found in one tree, but that was unusual.

3. Laboratory tests also showed that while moderately low temperatures were not a necessary prerequisite for pupation they did stimulate this phase of development, and brood so subjected had a lower mortality. The results of exposure to moderately low temperatures and subsequent development at room temperature are given in Table IV.

4. Initiation of the pupal stage in the spring is dependent on the occurrence of a continuous accumulation of effective temperature (above 50° F.). A developmental zero of 50° was chosen since little if any development occurred in brood stored in the cellar where the temperature averaged 50° F. prior to the first of June and 55° thereafter. However, the individual variation in effective temperature accumulation may range to approximately 20,000 hour-degrees, resulting in a considerable spread in brood development.

5. A study of the temperature requirements of pupation has indicated:

a. At a constant temperature of 85° F. the average accumulated hour-degrees necessary for pupation was 7522 ± 854 (9 ± 1 day), ranging from 4355 ± 889 (6 days) to 11151 ± 919 (13 days). The distribution of individual results are shown in Figure 6.

b. There is no evident relation between the length of the pupal period and the temperature accumulation prior to pupation.

c. The greatest theoretical accumulation necessary for development from overwintering stage to adult indicated by the range of individual variations was 31,550 ± 550 hour-degrees, while for the last adult reared from emergence cans the effective temperature accumulation was 33,880 hour-degrees.

d. In considering the development of the emerging brood as a whole, air temperatures may be taken as a fair index since bark temperatures will tend to revert to the same level as air temperatures because of the effect of such factors as shade on the upper bole and aeration of bark by woodpecker holes.

e. In the field the length of the pupal period will vary with the individual and with the effective temperatures obtaining during the period.

f. The curves in Figure 7, in which the average, maximum, and minimum length of pupal period is shown in relation to date of emergence, based on accumulated effective temperatures prior to that date of emergence, indicate that for emergence occurring during the first week in June the average length of pupation had been approximately one month (which checks with actual field observations).

6. A study of temperature in relation to emergence has indicated:

a. The time and duration of emergence varies from year to year as shown in the four year record given in Table V.

b. The time of first emergence in any one year is dependent on climatic conditions prevailing during the weeks prior to that emergence. Periods of effective temperature accumulation must obtain, and for emergence itself the daily temperature must rise above 70°.

c. The occurrence of peaks of daily emergence in relation to peaks of daily maximum temperature is shown in Figure 8.

d. In general the length of the period of emergence from any particular lot of bark was longer the earlier the emergence started, while shorter periods of emergence were indicated where emergence was more delayed.

e. As shown in Figure 7, the time required for effective temperature accumulation necessary for pupation (and hence emergence) becomes progressively shorter, resulting in a "catching-up" effect at that time when the curves fall off sharply, with a peak of emergence occurring at that time when length of pupal period has been the shortest.

f. The indicated beginning of the period of chief emergence (at that point where the curves start dropping) and the peak of emergence agree with rearing can emergence dates.

g. By drawing curves similar to those in Figure 7 for any particular year, as the season progresses it will be possible to foretell the emergence period by a short time, which information would be of value in predicting the end of effective control work.

h. Curves showing the rate and amount of effective temperature accumulation for the four years 1934-1937 (Figure 9) have been drawn with emergence dates marked for each year. It is indicated that emergence is dependent on amount of temperature accumulation without regard to date.

i. The data in Figure 9 can be closely correlated with temperature requirements of pupation previously discussed.

7. Eggs of M. californica required an average of 6077 ± 447 hour-degrees at a constant temperature of 85° F. for incubation, ranging from 4496 ± 482 to 6925 ± 449, or in terms of days, an average of 7.

Environmental resistance: Observations and studies have resulted in the following conclusions with regard to environmental resistance:

1. Unsuccessful egg development may be due to sterile eggs, rupturing of the chorion during oviposition, or parasitization. An Encyrtid parasite of a genus not previously known to parasitize eggs of Buprestids was reared and sent to Washington for identification.

2. Mortality of incipient larvae may result from "pitching-out", possibly as the result of abnormal resin production by the host in response to injury, or to unsuitable host material.

3. When broods enter the fast-growing stage success of development is dependent on the degree of competition, which is determined by the type of host material (standing tree, slash, etc.) and the prevalence of competing species. Flathead broods can develop on the upper side of slash material which is unsuitable for other species because of high subcortical temperatures. The amount of competition from M. gentilis in slash and windfalls is dependent on the abundance of incipient brood in the standing tree, and on the time the slash or windfall is created with respect to the emergence period of gentilis.

4. During the winter prepupal larvae are subjected to woodpecker feeding which may destroy a large proportion of the brood in standing trees. The Arctic 3-toed woodpecker, Picoides arcticus, is the species chiefly concerned.

Results of Other Special Studies.

Log rearings: During the 1937 season log rearings were initiated for a wide variety of material and the results of these rearings will be derived during the 1938 season. The 1936 log rearings which were concluded in 1937 formed the basis for emergence studies, larval growth records, and population studies.

Forced attacks: Observations of adult habits and activity were secured in cages which were used for forced attack studies. A summary of data is given in Table VI. Attacks were successfully initiated on both logs and poles. This material has been stored overwinter and will be continued in rearing during the 1938 season.

Caged tree studies: During the 1937 season introductions were continued on caged trees which were caged in 1936. A detailed measurement of growth of the three trees was made. The data on terminal growth are given in Table VII and the data on needle length in Table VIII. Apparently normal activity and the finding of hatched eggs indicated that an attack has been started.

Detailed analysis of feeding injury showed that feeding was more severe on the poorest tree and least on the best tree, and that on more vigorous trees feeding is more gregarious. The percent of twigs on which feeding injury occurred is given in Table X, and the percent of injured needles in injured needle groups is given in Table XI.

PLANS FOR THE 1938 SEASON

During the 1938 season studies will be continued to achieve a more complete understanding of the role flatheads play in forest insect depredations. Another season's study will largely round out the desired knowledge on biology and life history. More information should be secured on the length of incubation and the parasite factor in egg studies; the entrance of larvae from egg to cambial region is yet to be described. Particular attention will be paid to the seasonal history of populations and the influence of mortality factors on these populations. Continuation of forced attack studies will necessitate a certain amount of rearing which will yield incidental additional information on emergence.

The most important work of the coming season concerns the study of host relations. Particular attention will be paid to the physiology of the host, and the effect of incipient galleries on the host. The importance of slash will also be considered.

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TABLE I

Incipient Larvae Broods in a Single Stem

Sample	Year of Origin of Living Incipient Larvae							
	1934		1935		1936		1937	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1			3	7	9	21	30	72
2	9	33	6	22	1	4	11	41
3			12	25	15	31	21	44
Total	9	8	21	18	25	21	62	53

TABLE II

1936-37 Mortality of Incipient Broods

Sample	Year of Origin of Brood								
	1935			1936			1937		
	No. larvae		Percent mort.	No. larvae		Percent mort.	No. larvae		Percent mort.
	Live	Dead		Live	Dead		Live	Dead	
1	3	3	50	9	4	30	30	1	3
2	6	3	33	1	3	75	11	4	27
3	12	3	20	15	6	29	21	20	49
Total	21	9	30	25	13	34	62	25	29

TABLE III

Emergence of M. californica from Various Types of Brood Bark - 1937

Source	Overwintering condition	Average emergence		Largest emergence	
		Area sq.ft.	Beetles per sq.ft.	Area sq.ft.	Beetles per sq.ft.
Tree bole	Standing	89	1.96	16	3.94
Logs	Inside	14	13.14	8	16.88
Logs	Outside	153.5	1.17	8.5	4.59
1936 slash	Inside	96	4.11	17	11.82
1936 slash	In woods	55	.45	12	1.17
1936 windfall	In woods				
Lassen		91	.68	18	2.50
Modoc		21	1.14	21	1.14
1936 fire injured	Standing	6	.33	6	.33

TABLE IV

Development of Prepupal Larvae of *M. californica* Subjected to Moderately Low Temperatures

Lot #	A			B			C			D			E			F			G			H			I			J		
Date	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A	PP	P	A
Nov.28	5(45°)			5(45°)			5(45°)			5(45°)																				
Nov.30													5(45°)			5(45°)			5(45°)			5(45°)			5(RmTemp)			5(RmTemp)		
Dec. 3	5(32°)			5(32°)			5(32°)			5(32°)																				
Jan.11							5(RmTemp)			5(RmTemp)			5(RmTemp)			5(RmTemp)														
Jan.29	5			5			4			5			5			5			4			5			4			5		
Feb.17	5			4			3			5			5			5			3			5			4			4		
Feb.27													no change																	
Mar. 6													no change																	
Mar. 8	5			4			3			5			2	3		3	2		3			5			4			4		
Mar.12	5			4			3			5			2	3		1	4		3			5			4			4		
Mar.16	5(RmTemp)			4(RmTemp)			3			3	2		1	4		1	4		3(RmTemp)			5(RmTemp)			4			4		
Mar.19	5			4			3			3	2			4	1	1	4		3			5			4			4		
Mar.22	5			4			2	1		3	2			4	1	1	4		3			5			2			4		
													no change																	
Mar.24	5			4			2	1		3	2			3	2	1	4		3			5			2			4		
Mar.25													no change																	
Mar.26													no change																	
Mar.27	5			4			2	1		3	2			2	3	1	4		3			5			2			4		
Mar.29	5			4			2	1		2	3			2	3	1	4		3			5			2			3	1	
Mar.31	5			4			2	1		1	4			2	3	1	2	2	3			5			2			3	1	
Apr. 3													no change																	
Apr. 5	3	2		4			2	1		1	4				3	1	2	2	3			4	1		2			3	1	
Apr.6													no change																	
Apr. 7	3	2		4			2	1			3	1		2	3	1	2	2	3			4	1		2			3	1	
Apr. 8													no change																	
Apr. 9	3	2		4			2	1			3	1		2	3	1	1	3	2	1		4	1		2			3	1	
Apr.10	1	4		4			2	1			2	2		2	3		2	3	2	1		4	1		2			3	1	
Apr.13	1	4		3	1		2	1			2	2		2	3		2	3	1	2		3	2		2			1	3	
Apr.14	1	4		3	1		2	1			2	2		2	3		2	3	1	2		2	3		2			1	3	
Apr.15	1	4		1	1		1	2		1	2	2			3		2	3	1	2		2	3		2			1	3	
Apr.16		5		1	1		1	2		1	2	2			3		2	3	1	3		2	3		2			1	3	
Apr.17							1	1	1																			1	2	1
Apr.19							1		2											3										
Apr.29			5			1	1		2									3		2	1	2	2	1				1	1	2
May 4																				1	2	2		3						
May 10													no change																	
May 14																								3						
May 18			5			1	1		2			3			3			3				2		3						3

TABLE V

Time of Emergence of M. californica. 1934-37.

Year	Emergence		
	First	Peak	Last
1934	May 7	July 2	August 2
1935	Before June 17	July 17	August 27
1936	Before June 11	*	August 4
1937	May 23	July 16	August 17

* The 1936 peak probably occurred about July 19. The exact peak cannot be determined since the amount of bark in rearing was not constant.

TABLE VI

Results of Forced Attacks

Cage	Source of adults	Host material	Beetles introduced	Percent unaccounted for	Feeding	Mating	Eggs	Brood
D	Can emergence	Logs Poles Foliage	448	75	Yes	Yes	Yes	Yes
E	Field	Same	36	20	Yes	No	Yes	Yes
F	Can emergence	Logs Poles	116	10	No	No	No	No

TABLE VII

Terminal Growth of Caged Trees

Tree	Aver. Growth 1923-27	Aver. Growth 1928-32	Aver. Growth 1933-37	Aver. Growth 1923-37
IV	4.1	3.1	5.0	4.05
V	7.4	5.9	11.6	8.3
VI	3.6	4.5	9.8	5.97

TABLE VIII

Length of Needles on Caged Trees: Percent of Needles in Half Inch Class by Year Complement.

Tree	Year comp.	Length in Inches														
		3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
IV	1932			14.	14.	2.3	14.	55.8								
V			none													
VI								27.3	18.2	9.1	27.3					
IV	1933	1.8	8.0		25.9	30.9	13.4									
V					6.1	18.2	15.2	6.1	4.2	15.2	9.1	6.1		15.2		
VI						2.2	2.2	17.4	15.2	4.8	15.2	13.0				
IV	1934	4.0	2.0	24.0	38.0	22.0	10.0									
V					8.7	30.4	26.1	15.2	8.7	2.2	6.5	2.2				
VI					12.5	37.5	22.5	20.0	5.0	3.3						
IV	1935		4.0	10.0	26.0	32.0	18.0	10.0								
V					14.	16.	12.	22.	14.	18.	4.0					
VI					8.	10.	2.	12.	12.	22.	10.	24.				
IV	1936	2.6	6.5	16.1	26.5	24.5	13.5	10.3								
V					18.	20.	18.	12.	10.	10.	12.					
VI				10.	6.	8.	10.	36.	4.	16.		10.0				
IV	1937	5.8	3.8			7.1	41.	36.5	5.8							
V						7.3	9.1	14.5	10.9	9.1	3.6	27.3	9.1			9.1
VI		*2.5	5.0	9.4	3.8	11.3	3.8	17.0	15.1	22.6		9.4				

* 2½ inches long.

TABLE IX

Percent of Twigs Injured by Feeding

Tree	Percent of Twigs Injured According to Needle Complement Where Injury Occurs						No. beetles per twig
	1932	1933	1934	1935	1936	1937	
IV	16	22	20	22	52	48	.47
V	0	0	7	15	54	59	1.10
VI	0	3	4	10	22	53	.62

TABLE X

Percent of Needle Groups Injured on Tagged Twigs and Terminals According to Needle Complements

Tree	Needle Complement		
	1935	1936	1937
IV	9.9	69.1	61.6
V	2.3	32.3	31.4
VI	4.8	2.6	22.8

TABLE XI

Percent of Needles Injured in Injured Needle Groups

Tree	1935			1936			1937		
	No. needles			No. needles			No. needles		
	1	2	3	1	2	3	1	2	3
IV	72	16	12	40	38	22	32	43	25
V	79	16	5	56	36	8	52	36	12
VI	67	24	9	74	16	10	50	30	20

LIFE CYCLE OF A TYPICAL

MELANOPHILA CALIFORNICA

MIXED BROOD

(EMERGING BROOD IS TWO TO FIVE YEARS OLD)

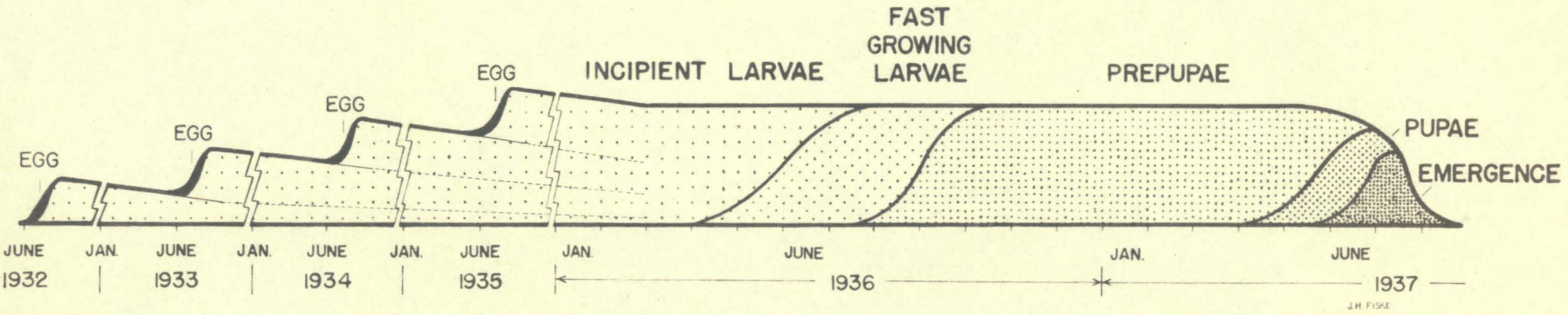

FIGURE 1

Figure 2. Effect of needle feeding by adults of Melanophila californica on ponderosa pine. (Photo #9921. by J. E. Patterson.)

Figure 3a. Eggs of Melanophila californica laid by adults emerged under caged conditions. Bark shaved away to show eggs. Modoc National Forest. 6/26/37. (Photo #10119 by K.A.Salman.)

Figure 3b. Placement of eggs of Melanophila californica on bark scales, collected in the field. Modoc National Forest. 6/21/37. (Photo #10110, by K. A. Salman.)

Figure 4. Prepupal larvae of Melanophila californica in pupal cell in wood of thin barked tree showing habit under those conditions. Modoc National Forest. 6/18/37. (Photo #10107, by K. A. Salman.)

Figure 5, a and b. Two aspects of galleries of larvae of Melanophila californica in a single log. Timing of attacks not ascertainable although strip killing was evident. Modoc National Forest. 6/21/36/ (Photos #9743 a and c, by K. A. Salman.)

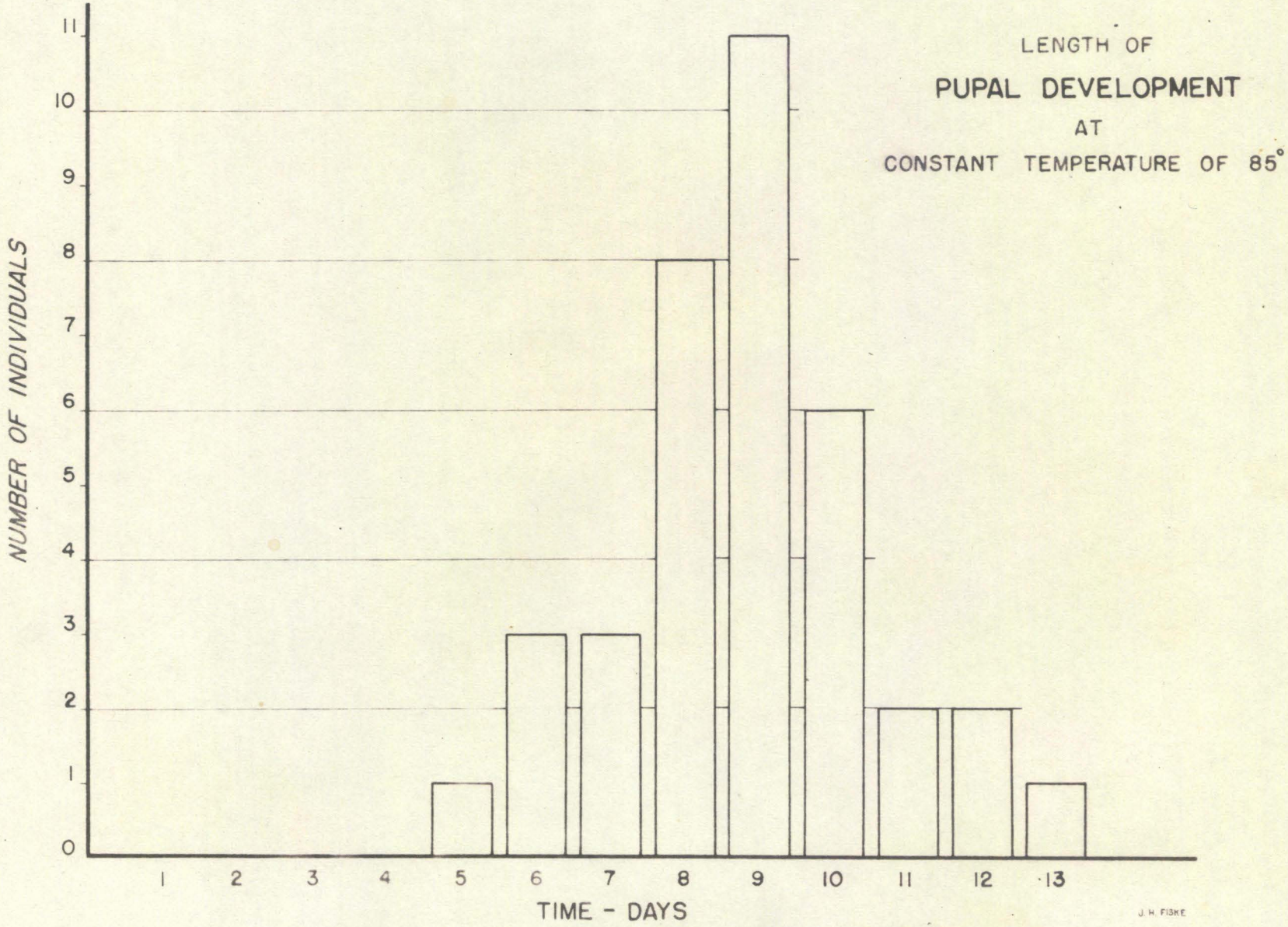
LENGTH OF
PUPAL DEVELOPMENT
AT
CONSTANT TEMPERATURE OF 85°
NUMBER OF INDIVIDUALS
0
1
2
3
4
5
6
7
8
9
10
11
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME - DAYS
J. H. FISKE

FIGURE 6

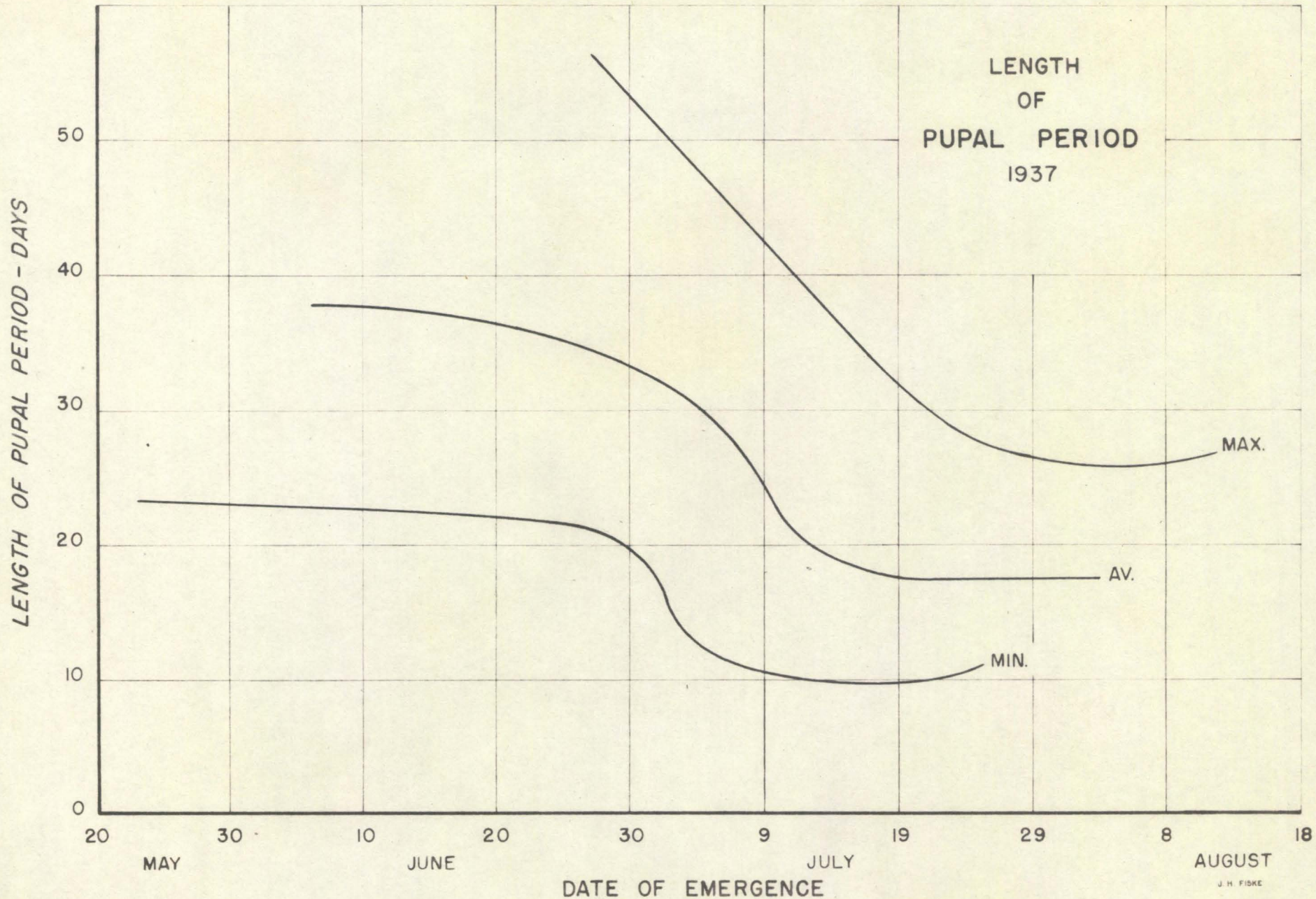
LENGTH
OF
PUPAL PERIOD
1937
LENGTH OF PUPAL PERIOD - DAYS
0
10
20
30
40
50
MAX.
AV.
MIN.
20
30
10
20
30
9
19
29
8
18
MAY
JUNE
JULY
AUGUST
DATE OF EMERGENCE
J. H. FISKE

FIGURE 7

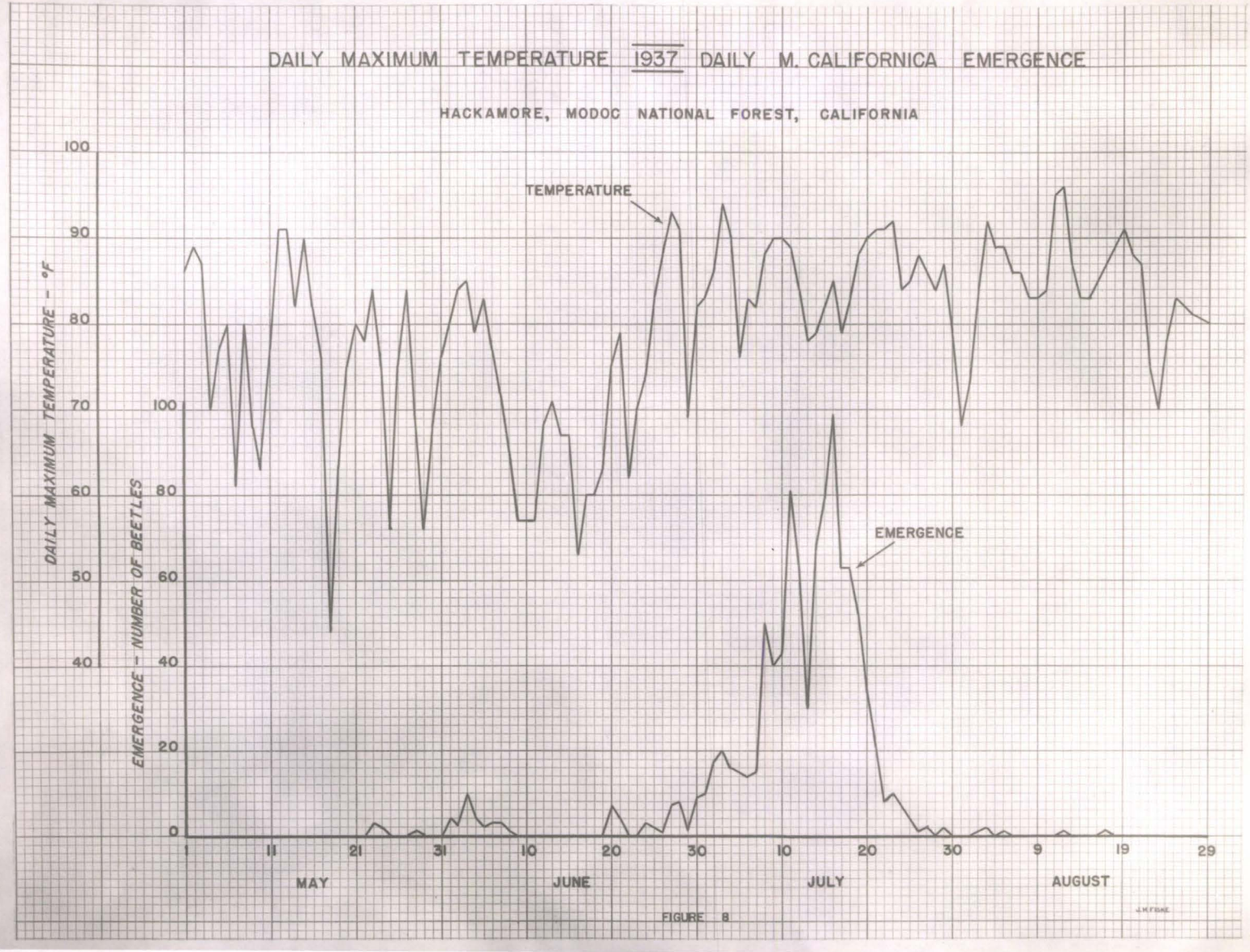
DAILY MAXIMUM TEMPERATURE 1937 DAILY M. CALIFORNICA EMERGENCE
HACKAMORE, MODOC NATIONAL FOREST, CALIFORNIA
DAILY MAXIMUM TEMPERATURE - °F
EMERGENCE - NUMBER OF BEETLES
TEMPERATURE
EMERGENCE
100
90
80
70
60
50
40
100
80
60
40
20
0
1
11
21
31
10
20
30
10
20
30
9
19
29
MAY
JUNE
JULY
AUGUST

FIGURE 8

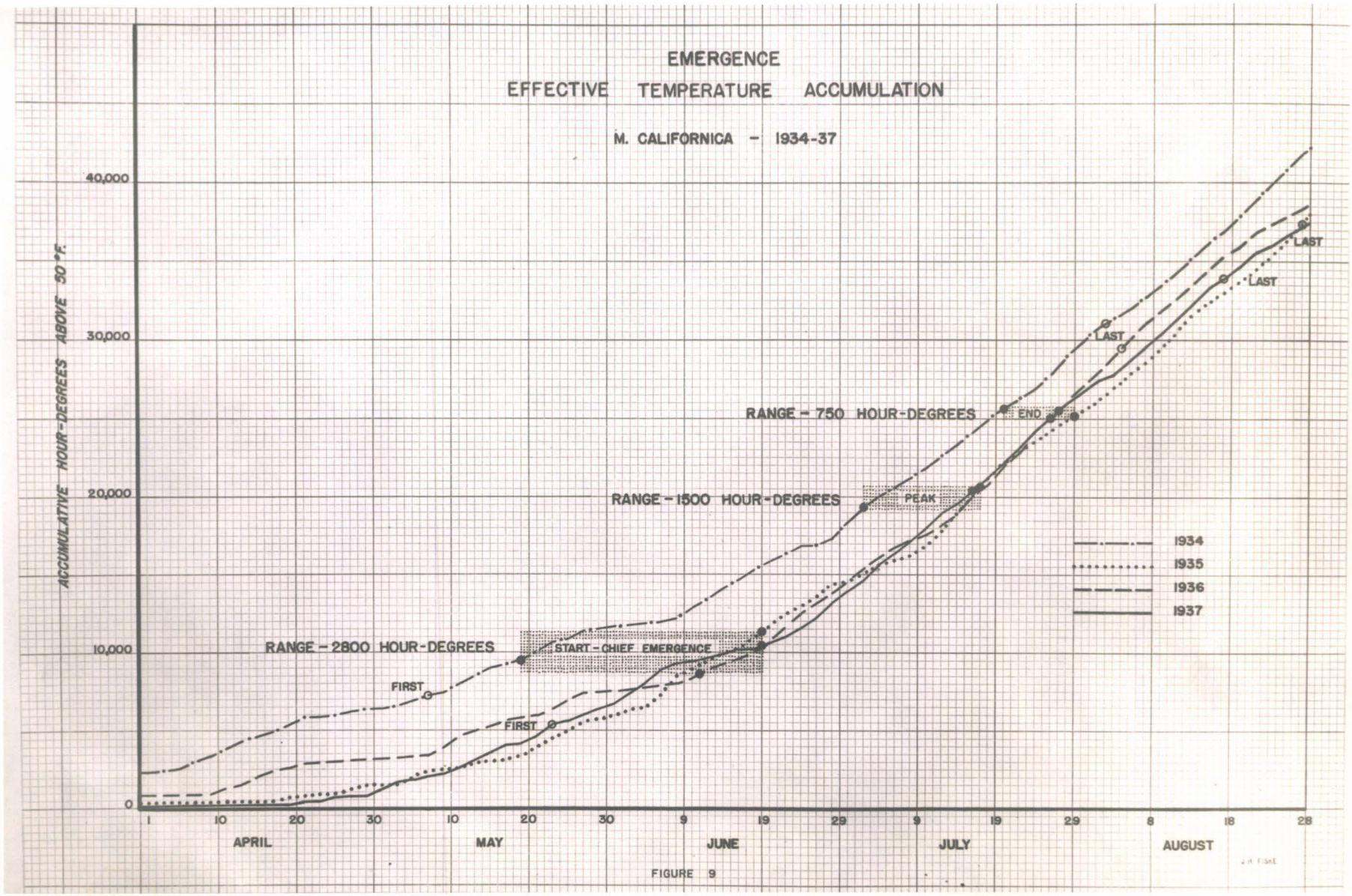
EMERGENCE
EFFECTIVE TEMPERATURE ACCUMULATION
M. CALIFORNICA - 1934-37
ACCUMULATIVE HOUR-DEGREES ABOVE 50°F.
40,000
30,000
20,000
10,000
0
RANGE - 750 HOUR-DEGREES
RANGE - 1500 HOUR-DEGREES
RANGE - 2800 HOUR-DEGREES
END
PEAK
START - CHIEF EMERGENCE
FIRST
FIRST
LAST
LAST
LAST
1934
1935
1936
1937
1 10 20 30 10 20 30 9 19 29 9 19 29 8 18 28
APRIL
MAY
JUNE
JULY
AUGUST

FIGURE 9